

Hazardous Ammonia Releases in Wisconsin: Trends and Risk Factors for Evacuation and Injury

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ABSTRACT

Objective: To assess trends in hazardous ammonia releases and risk factors for subsequent evacuation and injury.

Methods: Analysis of the Wisconsin Hazardous Substances Emergency Events Surveillance system data during 1993 through 1998.

Results: Ammonia releases (291) accounted for 13% of all reported chemical releases, but 26% of all releases that led to evacuations. The majority of non-transportation-related ammonia releases are the result of equipment failure or operator error (85.5%). Few ammonia releases are transportation-related (6.5%) or occur during extreme weather (14.4%). Extreme weather is not a risk factor for evacuation or injury following ammonia releases.

Conclusions: Ammonia releases are frequently the result of equipment failure or operator error and thus preventable. The majority of ammonia releases that lead to evacuation and injury are not the result of transportation accidents or weather factors beyond human control. Prevention efforts that focus on preventive maintenance, and worker training and awareness could reduce the burden of hazardous ammonia releases.

INTRODUCTION

Ammonia may be best known as a household cleaner, however, it is also used extensively in the commercial sector. For example, the food processing industry uses ammonia as a chemical coolant for refrigeration, and in agriculture ammonia is used as an additive to fertilizer. Over 17 million pounds of ammonia were reported to Wisconsin Emergency Management as being present in Wisconsin in 1999. This extensive use of ammonia leads to widespread possibility of accidental release and exposure to toxic concentrations. In fact, ammonia is one of the most commonly spilled chemicals in Wis-

consin and other states. A previous study that used data from nine other states documented that the risk of evacuation and injury following these spills is greater than for other chemicals.¹ Exposure to gaseous or liquid ammonia can cause severe burns and permanent damage to the lungs and eyes.

In order to help achieve the Wisconsin year 2000 goal of minimizing emergency events that lead to toxic chemical exposure,² the Agency for Toxic Substances and Disease Registry supports the maintenance of a Hazardous Substances Emergency Events Surveillance (HSEES) system in Wisconsin, as well as in 15 other states. This surveillance system monitors releases of hazardous substances throughout Wisconsin. Some of these can be severe; they receive extensive media coverage. For example, a 1992 train derailment in Douglas County, Wisconsin caused a release of aromatic distillates, which led to 103 injuries and the evacuation of more than 20,000 persons. Such media attention tends to lead to a conventional wisdom that these releases, and subsequent evacuation and injury, are usually the result of large-scale releases during transportation or extreme weather conditions beyond human control. However, many events receive less media attention, yet nationally, an estimated 15% of uncontrolled hazardous substance release events still result in evacuations, morbidity and mortality.³

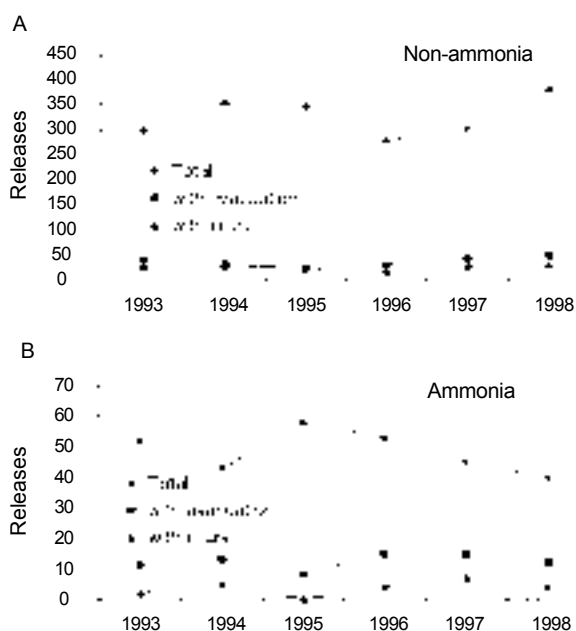
Is the conventional wisdom true, or are other factors that may be preventable responsible for ammonia releases and their consequences? Given the morbidity and financial costs of such consequences it is important to understand the trends and risk factors for ammonia spills and resulting injury and evacuation. Such understanding can help to better target prevention messages and identify high-risk circumstances associated with such events. To determine these trends and risk factors we analyzed data from the Wisconsin HSEES for 1993 through 1998.

METHODS

The Wisconsin HSEES manager is responsible for actively investigating and gathering relevant information concerning any hazardous substance emergency event in Wisconsin and recording these data with a

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Figure 1. Hazardous substance releases reported to HSEES, Wisconsin, 1993–1998



software program that is used throughout the states that implement HSEES. Sources of information include records of state environmental, agricultural and emergency agencies, local fire and police departments, as well as the National Response Center and the Hazardous Materials Information System of the US Department of Transportation.

We considered all events reported to HSEES in Wisconsin during 1993 through 1998, except 10 events that involved a combination of ammonia and other chemicals. These were excluded because we could not be certain whether any resulting evacuation or injury was the result of the ammonia. These 10 events included 2 that led to evacuation and 2 that led to injury. Hazardous substance emergency events are defined as uncontrolled or illegal releases or threatened releases of substances or their hazardous by-products. Reportable substances are any that might reasonably be expected to cause adverse human health effects, which include, among others, ammonia, all pesticides, chlorine, sodium hydroxide, and hydrochloric, nitric, phosphoric, acrylic, and hydrofluoric acids. Petroleum releases, however, are specifically excluded. Reportable releases are all those in which an actual release occurs and those where there is only the threat of a release but some action is taken as a result, such as evacuating persons from the area. Releases are defined as transportation-related when they have occurred during surface, air or water transport. Fixed-facility releases are defined as releases that occur at industrial sites, schools, farms or any other permanent location. All events are either

Table 1: Characteristics of uncontrolled ammonia releases in Wisconsin, 1993–1998.

Characteristic	N (%)
Total releases	291
Evacuation occurred	74 (27.0)
Injury occurred	22 (7.6)
Food processing/manufacturing industry	205 (70.4)
Agriculture industry	31 (10.7)
Transportation related	19 (6.5)
In summer	170 (58.4)
During day	164 (63.3)
On weekday	237 (81.4)
In commercial area	200 (70.2)
In residential area	169 (59.3)
Not in residential or commercial area	59 (20.7)
During extreme weather	41 (14.4)
> 100 pounds	87 (36.4)
Result of equipment failure or operator error**	130 (85.5)

* Not all percentages were calculated using 291 as the total because of missing information.

** Of 152 fixed-facility events only: This data was not collected for transport-related events or the remaining fixed-facility events.

fixed facility or transportation-related. An evacuation is defined as an event in which at least one person had to leave home or place of work. Injury data is gathered for all injuries related to the event.

Releases were categorized by season, time of day, period of the week, type of area where the release occurred, and amount of chemical released. Season was categorized as summer (May–October) or winter. Time of day was categorized as daytime (6 a.m. to 5:59 p.m.) or nighttime. Period of the week was categorized as weekday or weekend. Type of area was categorized as residential and/or commercial or not. We categorized all ammonia release sizes as at least 100 pounds or 10 gallons or less than these quantities. For simplicity, we refer only to the 100-pound threshold throughout the paper. One hundred pounds is the Environmental Protection Agency's threshold for mandatory reporting for ammonia releases.

SAS version 8 was used for all analyses.⁴ Crude relative risks (RR) were calculated with Taylor series confidence intervals (CI). Logistic regression was used to calculate adjusted odds ratios (OR) and Wald CIs. Characteristics of ammonia releases were included as potential confounders in the multivariate models if they could be related to the number of people potentially at risk for evacuation or injury following an ammonia release.

RESULTS

A total of 2251 releases of hazardous chemicals were reported to HSEES in Wisconsin during 1993 through

Table 2. Relative risk of evacuation following ammonia releases from fixed facilities by weather conditions, quantity released, and location, Wisconsin, 1993-1998.

Characteristic	Evacuation occurred	No evacuation occurred	Crude RR ¹ (95% CI)	Adjusted ² OR ³ (95% CI)
Not during extreme weather	59	156	Referent	Referent
During extreme weather	10	27	0.98 (.56-1.75)	1.07 (0.37-3.10)
<100 pounds	24	117	Referent	Referent
≥100 pounds	28	40	2.42 (1.52-3.84)	3.19 (1.49-6.86)
Outside	14	53	Referent	Referent
Inside	56	109	1.62 (0.97-2.71)	1.49 (0.63-3.48)

¹ Relative risk.
² Multivariate models included season, time of day, period of week, type of area, weather conditions, quantity released, and indoor vs. outdoor release.
³ Odds ratio.

Table 3. Relative risk of injury following ammonia releases from fixed facilities by weather conditions, quantity released, and location, Wisconsin, 1993-1998.

Characteristic	Injury occurred	No injury occurred	Crude RR ¹ (95% CI)	Adjusted ² OR ³ (95% CI)
Not during extreme weather	18	209	Referent	Referent
During extreme weather	2	37	0.65 (0.16-2.68)	0.34 (0.04-3.04)
<100 pounds	3	144	Referent	Referent
≥100 pounds	11	65	7.09 (2.04-24.66)	11.71 (2.38-57.65)
Outside	6	69	Referent	Referent
Inside	13	158	0.95 (0.38-2.40)	1.04 (0.26-4.17)

¹ Relative risk.
² Multivariate models included season, time of day, period of week, type of area, weather conditions, quantity released, and indoor vs. outdoor release.
³ Odds ratio.

1998 (Figure 1). The number of ammonia releases reported per year ranged from 40 to 58 (average=49). Ammonia releases accounted for 291 (13%) of all events reported to HSEES, range: 9%-16% per year (Figure 1B). During 1993 through 1998, a total of 282 releases led to evacuation and 163 led to injury. Ammonia releases accounted for 74 (26%) of 282 releases leading to evacuation, ranging from 20%-34% per year. Ammonia releases accounted for 22 (13%) of 163 releases leading to injury, range: 0%-21% per year. The corresponding relative risks for evacuation and injury following ammonia release compared with releases of other chemicals were 2.32 (95% CI, 1.84-2.93) and 1.05 (95% CI, 0.68-1.62), respectively. For 189 of the events reported to HSEES data on evacuation was missing.

The greatest number of hazardous ammonia releases occurred in the food processing or manufacturing industry followed by the agricultural industry (Table 1), and the most common sites for releases were commercial or residential areas. More ammonia releases occurred at fixed facilities, in summer, during the day, and during the week than during transportation, in winter, at night, and on weekends, respectively. Few ammonia

releases occurred during extreme weather conditions (e.g. rain, snow, ice, sleet, fog, high winds, extreme temperatures or weather disasters). More ammonia releases were of quantities less than 100 pounds than of larger quantities. However, among transportation-related releases with available data on the size of the release, only five of 16 were less than 100 pounds. Among releases at fixed facilities, a greater proportion resulted from equipment failure or operator error than other factors (e.g. power failures or deliberate damage).

Among ammonia releases with available evacuation data, 70 of 258 fixed-facility releases resulted in evacuations, compared with 4 of 16 transportation releases (RR 1.09, 95% CI 0.45-2.60) (RR=Relative Risk). All four of the releases during transportation that led to evacuation were of quantities of at least 100 pounds and none of them occurred during extreme weather conditions. Three of these four releases were on weekdays, two were in the summer, and one also led to an injury. One of these releases was during the day, two during the night; information was unavailable for one. Five of nine transportation releases that did not lead to evacuation were also greater than 100 pounds.

Twenty of 272 ammonia releases at fixed facilities

led to injury compared with two of 19 releases during transportation (RR 0.70, CI 0.18-2.77). Both of the releases during transportation that led to injury were during the day, in the winter and at least 100 pounds. Neither occurred during extreme weather. One of the two releases was during the week. Among 14 transportation releases with available size data that did not lead to injury 9 were greater than 100 pounds.

Among ammonia releases from fixed facilities, the greatest risk factor for evacuation or injury was the quantity of ammonia released. Releases of at least 100 pounds of ammonia had crude relative risks for evacuation or injury of 2.42 (95% CI, 1.52-3.84) and 7.09 (95% CI, 2.04-24.66), respectively, compared with those with smaller quantities (Tables 2 & 3). This association persisted when adjusted for season, time of day, day of week, type of area, weather conditions, and whether the release occurred indoors or outdoors. Ammonia releases that occurred inside had greater risk of subsequent evacuation, but not of injury (but both 95% CIs included one). Extreme weather conditions did not increase the risk for either evacuation or injury following ammonia releases. In fact, the risk of injury following releases decreased during extreme weather, but the confidence interval was wide and included one (Table 3).

DISCUSSION

Both the number of ammonia releases and the fraction that they comprise of all emergency events reported to the Wisconsin HSEES have been relatively consistent during 1993 through 1998. The number of ammonia releases that lead to evacuation and injury has also remained relatively constant during this period. Ammonia releases account for a disproportionately large fraction of events that lead to evacuation (26%) and thus a relative risk for evacuation compared with other chemicals significantly greater than one. This is consistent with previous analyses of HSEES data from nine reporting states,¹ and might be expected because the irritant properties of ammonia make it more likely to be quickly recognized and acted upon than other chemicals. Ammonia releases in Wisconsin, however, are no more likely to lead to injury than releases of all other chemicals, unlike the previous findings from HSEES data from nine reporting states where the risk of injury following ammonia releases was greater than for other chemicals.¹

The industries in which the most ammonia releases occur are agriculture and food processing or manufacturing. This is likely, in part, the result of these industries using the most ammonia. Nonetheless, this emphasizes the need for these industries in particular to consider initiatives to deal with hazardous ammonia release prevention. We also found ammonia releases to

occur more during the summer, on weekdays and during the daytime, similar to findings for hazardous chemical releases in another study.⁵

The greatest risk factor for evacuation or injury following ammonia releases was a quantity of chemical released of at least 100 pounds. However, many more releases of less than 100 pounds were reported to HSEES in Wisconsin than larger releases, and almost as many smaller releases that led to evacuation and injury as larger ones. Transportation-related releases tended to be large, and all transportation releases that led to evacuation or injury were large. But transportation-related releases were less than 7% of all releases.

Although conventional wisdom might suggest that extreme weather conditions would increase the risk for evacuation or injury following ammonia release, we did not find this to be the case. In fact, at fixed facilities, evacuation and injury were less likely to occur following ammonia releases during extreme weather conditions. In addition, less than 15% of all ammonia releases occurred during such conditions. None of the transportation-related releases that led to evacuation or injury occurred during extreme weather conditions.

A limitation of this study is that Wisconsin does not require that all uncontrolled releases of hazardous chemicals be reported. Therefore, although the HSEES manager attempts to track down all such releases, data in HSEES may not represent every uncontrolled release. In addition, reliable information is not available concerning the number of persons who were at risk for evacuation or injury; this factor will affect the likelihood of either of these outcomes occurring. Missing data on evacuation for some of the events could also affect the results, although we have no reason to believe that the missing data were differentially distributed.

SUMMARY

These data indicate that almost as many small-scale releases lead to evacuation and injury as large releases. Therefore, efforts to avoid small-scale releases should not be disregarded while concentrating on avoiding larger releases. Furthermore, while the sometimes spectacular nature of releases that result from extreme weather conditions beyond human control or large-scale transport accidents may attract a lot of attention, these account for only a small fraction of ammonia releases and are not any more likely to lead to evacuation and injury than other types of releases. A large majority of ammonia releases are the result of equipment failure or operator error—both preventable factors. These data suggest that attention to preventive maintenance, and worker training and awareness could be effective tools to reduce the financial and health burdens of ammonia releases.

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